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FIFTH BI-MONTHLY PROGRESS REPORT
UNIVERSITY OF ALASKA
ERTS PROJECT 110-13
May 31, 1973

A. TITLE OF INVESTIGATION: Glaciological and Volcanological Studies in the Wrangell Mountains, Alaska

B. PRINCIPAL INVESTIGATOR/GSFC ID: Carl S. Benson/UN 594

C. PROBLEMS IMPEDING INVESTIGATION: Abnormally heavy and persistent cloud cover in the Wrangell Mountains during passes of the satellite.

D. PROGRESS REPORT:

1. Accomplishments during reporting period: We are now receiving the first data from the Spring season in the Wrangell Mountains. We have completed a first look analysis of the images from 22 and 23 March, and 9, 10, 27 and 28 April.

The summit area is identifiable by cloud topography in some images but clearly visible only on the images from 28 April. There is evidence of considerable bare rock exposed by volcanic heating. The inner walls of the active crater are bare, a large snow cornice exists on the north rim of this crater and the outside, north-facing wall is bare. The north crater also has bare rock outcrops exposed.

The snow line can be identified on several glaciers in the area even when the summits of the higher peaks are cloud covered. We are also examining the foothills of the Wrangell Mountains for snow line features. There appears to be considerable evidence of wind erosion of snow in the northern foothills.

We have had a standing order with an experienced mountain-glacier pilot and photographer to take photographs of the summit area of Mt. Wrangell on days when the satellite is passing overhead. He has been ready to do this since the pass of 10 April. However, weather has been exceptionally bad and so far we have not been able to obtain any aircraft photo coverage.

We have received tapes for the data of

1010-20331	2 August 1972
1028-20333	20 August 1972
1046-20332	7 September 1972
1062-20221	23 September 1972
1081-20281	12 October

(E73-10665) GLACIOLOGICAL AND VOLCANOLOGICAL STUDIES IN THE WRANGELL MOUNTAINS, ALASKA Bimonthly Progress Report (Alaska Univ., Fairbanks.) 5 p HC $3.00 CSCL 08F G3/13 N73-25360 Unclas 00665

Digital printouts of Band 5 from 1062-20221 and of Band 7 from 1010-20331 and 1062-20221 have been made. We are in the process of analyzing these.

Plans for next reporting period: The snow melting is still proceeding up the slopes of the Wrangell Mountains. We expect that images covering this melt period will be available soon and hope for better cloud conditions. We are still standing by to photograph the summit area during a satellite pass. We also plan to make our trip to the summit area in late July or early August to be on the surface during one of the passes. This was postponed from last year.

E. SIGNIFICANT RESULTS: None

F. PUBLICATIONS

a) In preparation: Observations of the interaction of volcanic heat and snow cover on Mt. Wrangell, Alaska.

b) In Press: Benson, C. S., 1973, Snow Cover Surveys in Alaska from ERTS-1 Data, Proceedings of ERTS-1 Symposium on Significant Results from ERTS-1, NASA/GSFC, 5-9 March, 1973.

c) Published: None.

G. RECOMMENDATIONS: None

H. REVISED STANDING ORDERS: None

I. ERTS IMAGE DESCRIPTORS FORM: None

J. DATA REQUESTS: On 24 April 1973 we requested data from Mt. Erebus in Antarctica. Mt. Erebus was indicated as a test area in our approved ERTS A proposal. However, it was not included in the final contract because we were informed by NASA representatives that the data from Antarctica would not be available. We have now learned that imagery of Mt. Erebus is available and of excellent quality. Therefore we requested copies of the imagery taken over Mt. Erebus on 24 December 1972. The identification of this imagery is:

Band 4 - 1154 - 19322 -4
Band 5 - 1154 - 19322 -5
Band 6 - 1154 - 19322 -6
Band 7 - 1154 - 19322 -7

We were informed that this data request was rejected because the Mt. Erebus test area, although in our original proposal, was removed by NASA because no imagery would be available. Since the imagery is indeed available we would like to obtain this one sample of it to attempt the comparative study which was part of the original proposal.

'FINDING FAULTS' WITH ERTS-1 IMAGERY

by Larry Gedney

The following introduction is part of the University of Alaska ERTS-B proposal submitted for the continuance of the investigations begun under ERTS-A. A portion is also taken from the Project 12 section of the ERTS-B proposal. These are included here to give more background to the ensuing article.

--Editor's Note

INTRODUCTION

The Earth Resources Technology Satellite Program, with its demonstrated capability for economical large scale surveys, provides a unique opportunity to narrow a great environmental knowledge gap which impedes planning at a critical juncture in the history of Alaska's economic and social development. . . .

This problem has been recently and forcefully manifested in several ways, chief among which are:

1) The controversy surrounding the proposed construction of the trans-Alaska pipeline from the arctic coast to the southern port of Valdez, and the recent U.S. Appellate Court decision denying the permit for its construction.

2) The deterioration of fisheries resources in the Alaska coastal zones and continental shelf. This results partly from a poor environmental knowledge of these regions.

3) The establishment by Congress and the Alaska State Legislature of the Joint State-Federal Land-Use Planning Commission. This Commission has the awesome task of recommending by 1975 a comprehensive land-use plan for Alaska's 375 million acres, thereby assisting the federal government, the State of Alaska, and the Alaska Native Corporations with the selection of 220 million acres of public domain lands.

The basic data for informed land-use research and planning in Alaska is very sparse and often outdated. Therefore, even the first task of planning in Alaska on a regional basis is laboring under severe handicaps. Alaska is so vast, and the Arctic so varied, that this environmental gap will not be bridged soon by conventional means.

In December 1969, the State of Alaska and the U.S. Department of the Interior co-sponsored a symposium entitled "The Use of Remote Sensing in Conservation, Development, and Management of Natural Resources of the State of Alaska." In his introductory remarks to the symposium, the Honorable Walter J. Hickel, then Secretary of the Interior, said:

"....The conservation, development, and management of the natural resources of the State of Alaska are of concern to all the people of our country. Our nation's largest State is rich in resources vital to our continued well-being and economic growth.

The sophisticated techniques of remote sensing offer advanced cost-effective means of locating, monitoring, classifying and inventorying mineral deposits, recreation areas, forest lands, coastal zones, fisheries, water supplies and energy potential. The highly sensitive instruments of this relatively new field can yield otherwise unobtainable information about the land and its effective use. Under the Department of the Interior's Earth Resources Observation Satellite (EROS) Program, we are beginning to assess what these new tools can do for us from aircraft and satellite platforms. In 1972 the National Aeronautics and Space Administration will launch the first Earth Resources Technology Satellite (ERTS-A) to provide small-scale synoptic and repetitive views of the earth and its resources.

Because of Interior's intimate participation in this experiment, we anticipate that the benefits from these early techniques will be greatest in developing areas. I can, therefore, think of no better place to apply this technology than in Alaska...."

In recognizing this promising potential, and with the wholehearted support of government agencies in Alaska, the University of Alaska proposed in 1971 an interdisciplinary program of ERTS-A analyses involving projects, twelve of which were eventually included in the ERTS-A contract with NASA. All of these twelve projects are reaching the state of fruition, and some have already produced results of considerable importance and utility....

Initial target objects for ERTS-A Project 12 were chosen largely on the basis of comparing current seismicity maps (Prepared at the Geophysical Institute) with the most recent information on faults and fault systems which could be obtained from the U.S. Geological Survey and other sources. Linear zones of epicenter concentrations where no faults were mapped were obvious objects of interest. At least two of these lineaments have subsequently been identified as major faults by independent workers. However, the most significant findings have come from areas in which the investigators had not expected to find anything of particular interest. They have identified in these areas such previously unmapped features as faults, joint systems, and other structures which aid in the interpretation of the nature of the tectonic deformation in central Alaska.

The interpretive methods used were simple and straightforward. They included visual analysis of the ERTS images and projection of the 70mm positive transparencies so that group discussions could be held, manipulation of the 70mm negatives using different exposure times to best display the particular object of interest, and the construction of false color scenes by reconstituting color images from the individual black and white photographs.

Larry Gedney is an Associate Geophysicist and is the principal investigator of Project No. 12 of the University of Alaska's ERTS program. He is with the Seismology Department of the Geophysical Institute, University of Alaska, Fairbanks.

University of Alaska
NASA Contract NAS5-21833
Project No. 110-12

BACKGROUND

Along most of the highly seismically active Aleutian chain, earthquakes result as two crustal plates collide, with the southern plate underthrusting the northern plate along the line of the Aleutian Trench. Underthrusting of the type seen in the Aleutians has been thought to occur exclusively in oceanic trench-arc systems. However, as seismographic coverage in Alaska has improved in recent years, it is now being found that underthrusting is continuous from the Aleutian Trench, through Cook Inlet and along the eastern flank of the continental Alaska Range as far north as Mt. McKinley, with focal depths as great as 250 km.

Contrasted with this, north of Mt. McKinley and the Alaska Range there is a broad zone of shallow seismicity at least as far north as the southern Brooks Range. Focal depths here seldom exceed 40 km, and there is no evidence of the type of underthrusting that is seen in the south, although the areas are laterally contiguous. Since 1904, eight earthquakes of between magnitude 6.0 and 7.8 have occurred in the Alaskan interior. Since shallow earthquakes are potentially more hazardous than deep ones because they are closer, a matter of primary concern to this investigation was to combine seismic data with ERTS imagery in order to identify features with which to define the stress system responsible for the seismicity of the Alaskan interior. A logical outgrowth of the findings will be a better understanding of seismic risk across the area, with its obvious implications to land use planning and basic building codes.

SOME PERTINENT FINDINGS FROM ERTS 1 IMAGERY

In October, 1968, an earthquake of magnitude 6.5 occurred in the Minook Creek Valley northwest of Fairbanks. Figure 1 is a mosaic composed of portions of six ERTS-1 images. Figure 2 is a key to the ERTS mosaic; the solid lines indicate faults already mapped, while the broken lines represent faults not recognized prior to ERTS imagery. Minook Creek appears in the upper left center at approximately 65.4° N., 150.1° W. Prior to the 1968 earthquake, this feature was not recognized as a fault. Since that time, aftershock studies, source mechanism studies, and geologic field mapping have revealed that it is, indeed, a left-lateral fault. Had ERTS imagery been previously available, this conclusion would undoubtedly have been reached long ago. The extreme sharpness of the stream incision, the textural and tonal differences across the valley, and the series of parallel fractures in the surrounding mountains would have left little doubt. Although the left-lateral nature is not obvious on the Minook Creek fault, the third parallel feature to the east shows it quite well, with truncation of mountain lobes on both the north and south sides of the ridge line.

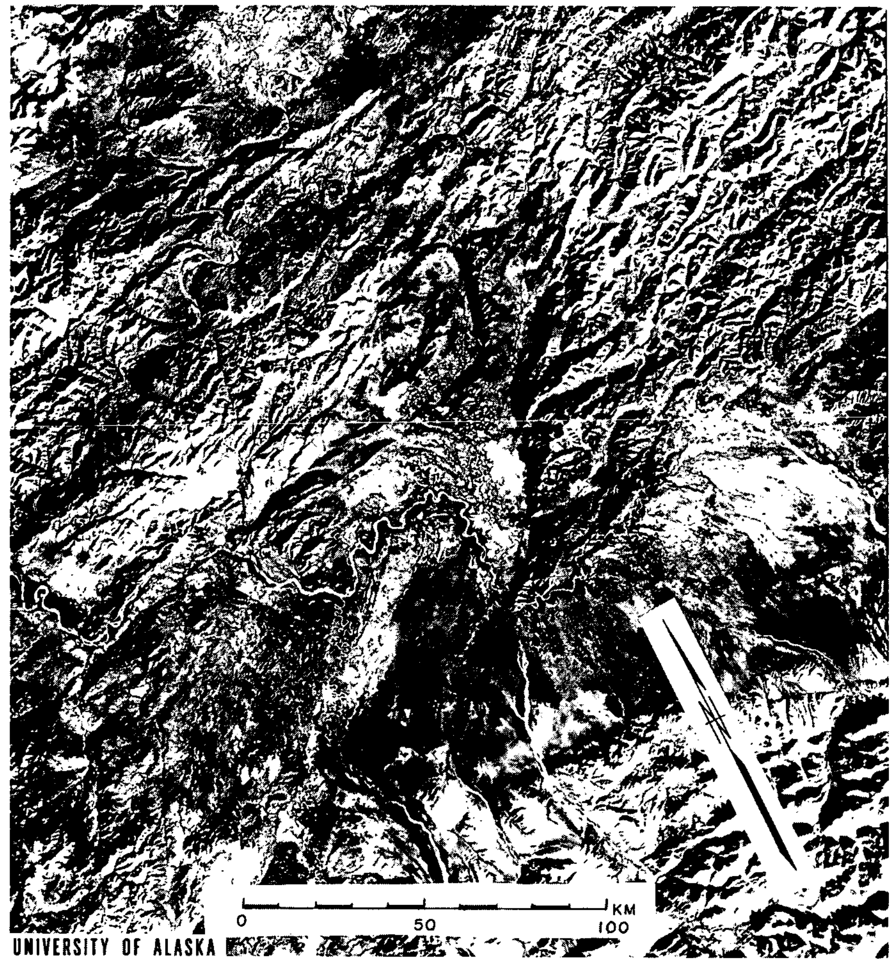

FIGURE 1. Mosaic of portions of six ERTS-1 images (Image ID Nos. E 1104-20554, E-1104-20560, E-1104-20563, E-1105-21012, E-1105-21015, and E-1105-21021).

On closer inspection, one sees that the Minook Creek fault is only part of a large scale fracture system involving many other linears. Parallel features can be seen in the mountains across the Yukon River, where they affect tributary drainage, and two long lineaments are seen in the Kuskokwim Mountains to the southwest. Textural changes occur across the latter two, although they are lost in the alluvium of the Tanana River at their northern ends.

An almost equally impressive set of conjugate fractures intersects the Minook Creek complex at an angle of 55°, and strikes southeast to the Alaska Range. This is roughly the dihedral angle at which most brittle substances would be expected to fail if compressive stress is applied in a direction bisecting the two sets of fractures. In this case the direction is at an azimuth of about 345°, roughly perpendicular to the trend of the Alaska Range. The conjugate set of

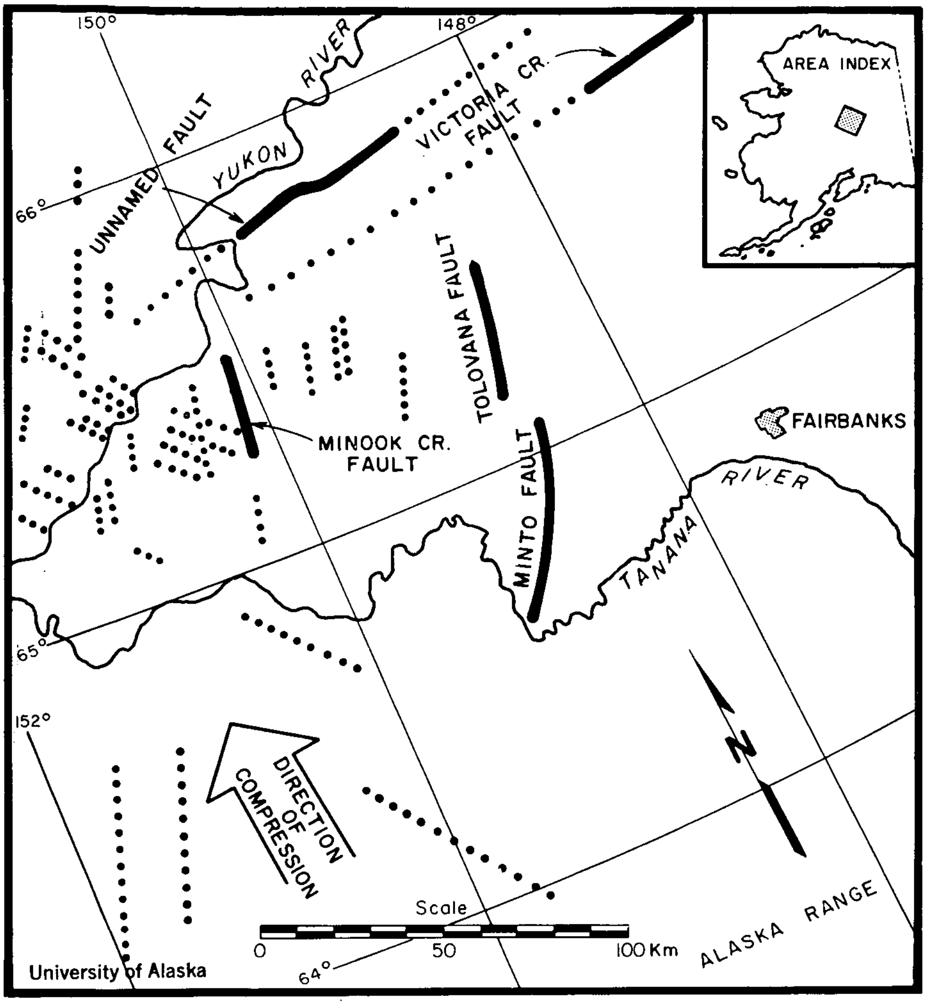

FIGURE 2. Key to ERTS mosaic: solid lines indicate faults already mapped, broken lines represent faults not recognized prior to ERTS imagery.

fractures is most apparent in the Ray Mountains, across the Yukon River from Minook Creek, but it is also visible in the mountains around Minook Creek, south of the Tanana River, and near the bottom center of Figure 1. The latter lineament appears to truncate the small mountain near its center.

The implication is clearly that earthquakes in this area are the product of compressive stress radiating outward from around the great bend in the Alaska Range, and that this stress system has resulted in the formation of a conjugate shear system with earthquakes occurring along the individual fractures. A mechanism of this sort agrees well with the fault plane solution obtained for the 1968 earthquake, and with one obtained for a magnitude 6.0 earthquake near Fairbanks in 1967. For the latter event, a nearly north-south azimuth of compresive stress was obtained, nearly perpendicular to the Alaska Range at this point, as was true with the Minook Creek event. The question which now arises is, "What causes the compression?" A possible explanation is that the forces which caused the Alaska Range to "buckle," forming the great 90° bight in the range at Mt. McKinley, are still at work. The primary cause may be axial compression on the "ends" of the range, or it may be a result of deformation resulting from collision with the northwesterly moving Pacific plate. Whatever the basic energy source, it would seem plausible that further buckling of the range would result in outwardly directed compressive stress around the outside of the bend, and would probably result in the kind of conjugate fracture pattern that has been discussed.

CONCLUSIONS

While much of what has been said to this point has dealt with tectonic setting, the real point which should be made is this: It is possible, with ERTS imagery, to delineate seismically active faults which may otherwise go unnoticed. Certainly the Minook Creek fault (site of the magnitude 6.5 earthquake in 1968) would have been recognized long ago, had ERTS imagery been available, and its freshness of appearance would have labeled it as being recently active. In addition, the fact that the 1968 earthquake occurred within less than ten miles from the site of the proposed Rampart Dam would have been a factor in formulating its design characteristics. Further, it bears pointing out that the site for the proposed Rampart bridge and trans-Alaska oil pipeline crossing of the Yukon River is very near the Minook Creek fault if it extends to the north, and that the proposed route also crosses the two strong lineaments in the upper top center of Figure 1. Particularly in Alaska, where these areas are remote and accessible only at great time and expense, ERTS imagery shows great promise as an aid in construction planning, zoning, and seismic risk evaluation.

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HICKEL REPORT NOW AVAILABLE

Geothermal Energy: A Special Report by Walter J. Hickel, published by the University of Alaska and sponsored by the National Science Foundation (RANN), is now available for ordering. Copies of the report can be ordered for $3.00 apiece or microfishe can be ordered for $1.45. The accessions number, P.B 222 326 with the money should be sent to:

United States Department
of Commerce
National Technical Information Service
Springfield, Virginia 22151

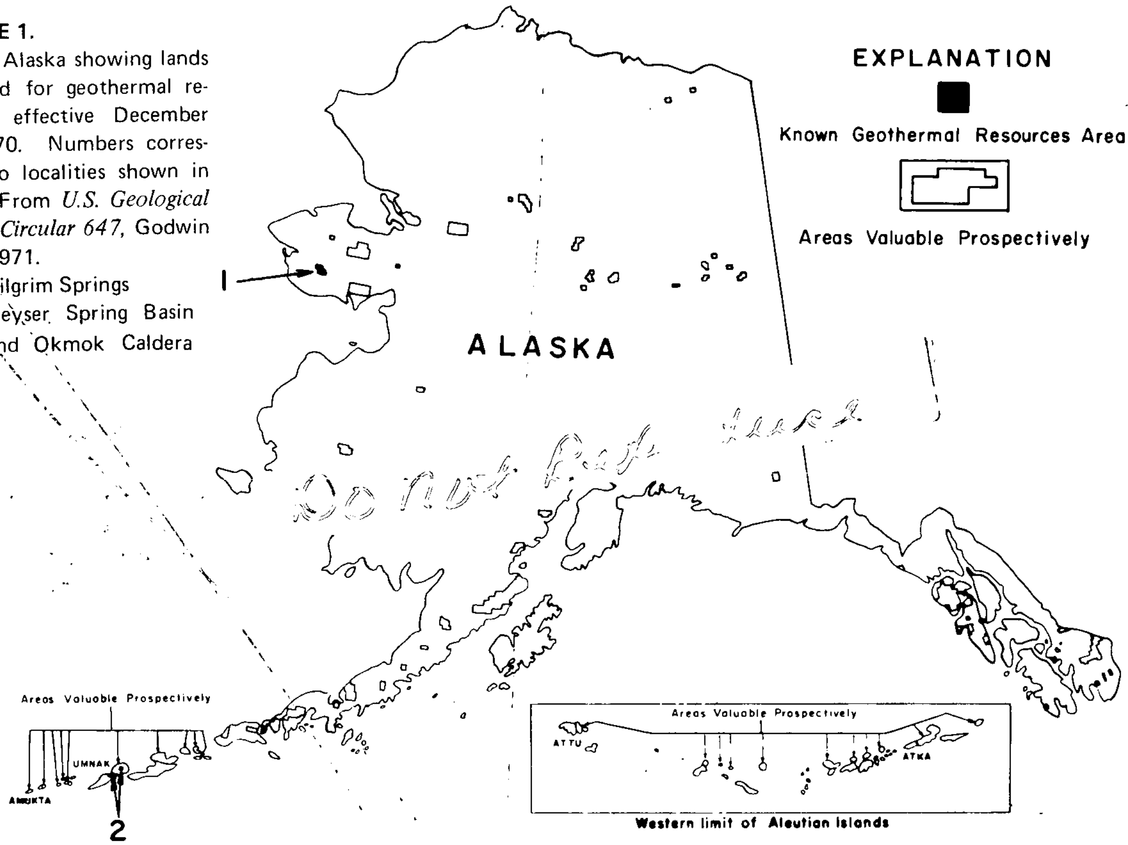

FIGURE 1. Map of Alaska showing lands classified for geothermal resources effective December 24, 1970. Numbers correspond to localities shown in inset. From *U.S. Geological Survey Circular 647*, Godwin et al., 1971.
1. Pilgrim Springs
2. Geyser Spring Basin and Okmok Caldera

ALASKA'S GEOTHERMAL RESOURCE POTENTIAL

By Robert B. Forbes and Norma Biggar

GEOTHERMAL ENERGY IN THE NATIONAL INTEREST

Until the last few years, the United States has not shown much concern or interest in the assessment or development of its geothermal resources. More recently, however, possible world-wide energy shortages, growing pollution problems and the awakening of a national environmental conscience have developed an accelerated interest in geothermal energy. This new cognizance has been reinforced by the Congress, with the passage of the "Geothermal Steam Act of 1970" (84 Stat 1566), which authorizes and delineates geothermal resource "provinces" and "areas," and defines leasing and regulative policies for federal lands.

U.S. Geological Survey Circular 647, "Classification of Public Lands Valuable for Geothermal Steam and Associated Geothermal Resources" (Godwin, et al., 1971), presents the criteria for determining which Federal Lands are classifiable as geothermal steam and associated geothermal resources under the Geothermal Steam Act of 1970 (84 Stat 1566). This report includes a map of Alaska showing lands classified for geothermal resources, as of December 24, 1970 (Figure 1).

GEOTHERMAL GRADIENTS AND HEAT FLOW

Sub-surface temperatures rise with increasing depth in the earth, but depth/temperature relations (thermal gradients) are not the same, as measured at world-wide localities. Although the thermal gradient is a rather good parameter for evaluating geothermal potential, heat flow, a somewhat different value, may be more meaningful for inter-regional comparisons. Heat flow is expressed as micro-calories/cm^2/second, and differs from measurements of the thermal gradient as it considers the thermal conductivity of the rocks in which the measurements were obtained; and it also includes a time function, which expresses the rate at which thermal energy or heat is being conducted upward toward the surface of the earth.

Various lines of evidence indicate that the thermal gradient is not linear from the crust to the core of the earth. In this discussion, however, we are not too concerned about the deep structure of the earth, as the first 10 kilometers of the crust constitute the zone of economic importance for geothermal energy resources based on present technology.

The average thermal gradient, as determined from drill holes, mine workings, etc., is about 30^{o}C/kilometer. The thermal gradient is believed to be greater in the oceanic rather than the continental crust in areas of "normal" heat flow. There is no significant difference in the average heat flow as determined for the ocean floors and the continents.

Dr. Robert Forbes is a Professor of Geology and has a joint appointment with the University of Alaska's Geophysical Institute and Department of Geology, University of Alaska, Fairbanks, Alaska.

Norma Biggar is a graduate student working for her M.S. degree in Geology and holds a part-time graduate assistantship with the University of Alaska's Geophysical Institute, Fairbanks, Alaska.